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THE CONDOS METHODOLOGY FOR EVALUATION OF RADIATION EXPOSURE FROM CONSUMER PRODUCTS[a]

by

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Requests to incorporate and to distribute radioactive materials in products intended for unrestricted use by the general public must be evaluated carefully by agencies with the appropriate regulatory authority. In the case of naturally occurring and accelerator-produced radioactive materials (NARM), the states are the regulatory agencies. Recognizing this, the Conference of Radiation Control Program Directors, Inc. established a Task Force to develop guidance for each state's evaluation of products containing NARM. This Task Force is about to prepare a guide for evaluation of such products and is considering use of a systematic methodology, called CONDOS, to make the evaluations. The purpose of this paper is to describe the CONDOS methodology, that is, what it does, how it operates, and what it has been, and can be, used for.

The CONDOS methodology is a tool for estimating radiation doses to man from exposures to radionuclides incorporated in consumer products. It consists of two parts: (1) an outline, checklist, and selected data for modeling the life span of a product or the material from which it is made; and (2) a computer code that uses the life-span model to calculate radiation doses to exposed individuals and population groups. Part 1 of the methodology has been described previously,[1] and both parts will be described in the final report on the methodology.[2]

As illustrated by Fig. 1, a consumer product may proceed from manufacture to ultimate disposition via many possible pathways. The product is manufactured; distributed by one or more agencies; used in the intended manner and, possibly, in some unintended ones; discarded; and disposed of or recycled. Transportation methods interlace the entire life span and accidents are always possible.

The CONDOS methodology is designed to take the chaotic picture of Fig. 1 and convert it to the organized, but flexible, scheme depicted in Fig. 2. The first row of boxes represents information collection. Rows two through six represent use of the information to construct a life-span model for the product. The remaining boxes represent operations performed by the computer code.

All available information about the product to be evaluated should be collected from all possible sources (e.g., from manufacturers, distributors, retailers, and users). Information will include factual data, informed testimony, opinion, and wishful thinking. In addition, a useful guide is available for modeling transportation and distribution.[3] All information must be analyzed and synthesized by the modeler into a manageable, realistic model that represents the complicated life span of a consumer product.

The modeling procedure prescribed by CONDOS is outlined in Fig. 2 and illustrated in Table I for a hypothetical tableware product. (Numerical values are given in Tables I and II only for illustrative purposes; they are not the result of an actual assessment.) A product's life span is divided into a series of rather general categories called stages (Fig. 2 lists five in row two and Table I lists four, as the leftmost entries). These, in turn, are divided into more specific categories, called substages (row three, Fig. 2 and second leftmost entries, Table I). The groups of persons involved in each substage are then identified and quantified (row four, Fig. 2 and third leftmost entries, Table I). Finally, specific, representative events during which group members may be exposed to the radionuclides in the product are identified and the conditions under which the exposures may occur are defined (row five, Fig. 2 and the remainder of Table I).

Table I contains four stages, each having one substage and several groups of persons who are assumed exposed during one event (truck drivers and helpers were assumed to participate in three events). In practice, a model can contain any numbers of stages, substages, groups, and events; the numbers chosen would be limited only by practical considerations. This point is illustrated in the applications of the methodology cited below.

When modeling is completed, the computer code uses the event descriptions to calculate radiation doses to individuals participating in the selected events (rows 7 and 8, Fig. 2). Doses are calculated separately from two external and two internal exposure modes. External exposures include those from photons emitted directly from an integral product (DIR) and those from photons emitted by airborne radionuclides that may have escaped from the product (EM). Internal exposures are 50-year dose commitments from intakes of radionuclides by inhalation (EN) and by ingestion (ENG) during the specified period of exposure. The total dose to an individual is the sum of the doses received via each of the four exposure modes. This dose is converted (row nine) to a population dose (ED) by multiplying the individual dose by the number of persons so exposed [i.e., by the number of persons in the group being considered (NM) and the probability (EVPROB) that all group members will be so exposed].

The above calculations are repeated for each event in which a group is involved. When all events for a group have been processed, the resultant ED's are summed to give a total group population dose (TGD). Similarly, the TGD's are summed to give substage population doses (TSSD); these are summed to give stage population doses (TSD); and the sum of these is the total population dose for the product (TPD) for the specified period of assessment.

Table II is an output sheet of doses calculated for the hypothetical tableware modeled in Table I. Dose estimates are given for each exposure pathway and for each event. Population doses are given for each event, group, substage, stage, and the product. An estimate is also given of the beta-dose to skin from handling the product (see footnote). Other output formats are possible, but Table II illustrates the maximum amount of information that can be put in a readable output table.

Some features of the CONDOS calculational capability include: (1) calculation of doses to nine body organs; (2) product representation by one of eleven source geometries; and (3) internal dose estimation using radiation dose conversion factors that use either ICRP-2 metabolic models[4] or the Task Group Lung Model and new metabolic models[5] to estimate deposition and retention of radionuclides in body organs.

Applications of the CONDOS methodology include:

1. Assessments of specific products. Potential radiological impacts on man can be evaluated from specific products, such as timepieces containing ^{3}H gas (ref. 6) or ^{3}H or ^{147}Pm paint (ref. 7), spark-gap irradiators containing ^{60}Co for use in oil burners,[8] and thorium radiators in neutron dosimeters.[9]
2. Generic assessments. Radiological impacts can be evaluated for a class of products or for use of a radioactive material in industrial processes, such as recovery and reuse of contaminated scrap metals, which involves many possible, but uncertain, uses of the materials.[10-12] By looking at many typical uses and exposure situations, it is possible to obtain a range of likely doses from reuse of the contaminated metals.

3. Sensitivity analyses. Frequently, it is desirable to vary assumed exposure parameters and establish a range of possible doses. Also, critics may disagree with some parameters used and, hopefully, will suggest replacement values. These can be inserted easily into the computerized data file and used to calculate a new set of dose estimates.

4. Compare radionuclides. By changing only a few input cards, it is possible to compare doses from many nuclides under identical conditions. For example, in the assessment of scrap metal from decommissioned nuclear facilities, 26 radionuclides (some were actually a composite of several nuclides in decay chains) were examined to determine, among other things, which might give the highest doses for the various modes and scenarios of exposure.[11] Another application is in determining the effect of uncertain contaminants. For example, very small concentrations of ^{232}U might be found in uranium-contaminated metals recovered from gaseous diffusion plants. If present, this minute contaminant could deliver as much as 80% of the doses from recovery and reuse of the metals.[12]

5. Compare product designs. Suppose that a product has been assessed and the manufacturer wants permission to make a design change (e.g., to delete or add a shield). This can be done quickly and simply by changing the few data cards pertaining to the source (product) description and recalculating the doses.

To summarize, the CONDOS methodology is a versatile tool for evaluating radiation doses to man from a variety of exposure situations. Although designed for evaluating consumer products, CONDOS may be used to evaluate doses from exposures to commercial and industrial products and processes.

The methodology gives a prescription for modeling a process or the life span of a product and provides a computer code for using the model to calculate radiation doses.

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Table I. Components of the life span model and event descriptions assumed for a hypothetical tableware.

	Probability of group member being in event	Duration of direct exposure (hr/year)	Effective amount of uranium in source (g)	Distance from source (cm)	Attenuation factor	Duration of immersion (hr/year)	Concentration of uranium in air (g/cm^3)	Duration of inhalation (hr)	Amount of uranium ingested (g)
Transport									
Truck – long haul									
Drivers – helpers (510)[a]									
Driving	1	28	4,000	650	0.8	–	–	–	–
Stops – rest	1	8	4,000	9,000	0.6	–	–	–	–
Accident – cargo fire	.0035	–	–	–	–	0.08	1.2E–10	0.08	
Persons at stops (5.1E3)									
Normal activities	1	1	4,000	9,000	0.6	–	–	–	–
Persons along route (3.57E7)									
Normal activities	1	0.02	4,000	15,250	0.3	–	–	–	–
Motorists (3.57E4)									
Passing trucks	1	0.02	4,000	3,050	0.6	–	–	–	–
Use									
Commercial use									
Dishwashers (500)									
At work	1	2,000	375	90	1	2,000	8.3E–16	2,000	
Servers – waiters (1000)									
At work	1	1,000	500	152.5	1	250	8.3E–16	250	–
Patrons (7.5E6)									
Dining out	1	4	500	61	0.9	–	–	–	1.0E–4
Passersby (9.99E7)									
Normal activities	1	0.02	1,000	18,000	0.5	–	–	–	–
Disposal									
Landfill									
Collectors (30)									
At work	1	1	100	90	0.7	–	–	–	–
Passersby (1.0E5)									
Passing cans	1	0.02	100	150	0.7	–	–	–	–
Fill workers (40)									
At work	1	1	500	9,000	0.5	–	–	–	–
Area users (1.0E6)									
Normal activities	1	8	500	30,000	0.5	–	–	–	–
Emergencies									
Transport accident									
Firemen (5)									
Fighting fire	1	1	50,000	3,050	0.7	–	1.2E–10	1	–
Policemen (2)									
Crowd control	1	1	50,000	7,100	0.7	–	1.2E–10	1	–
Medical team (3)									
First aid	1	0.25	50,000	7,100	0.7	–	1.2E–10	0.25	–

[a]Numbers in ( ) are the assumed number of group members.

Table II. *Estimated radiation doses to man from hypothetical tableware under assumed conditions of exposure.*

Population radiation dose from the distribution, use, and disposal of consumer products containing radioactive materials

Sample problem for condos – *hypothetical earthen* tableware coated with ceramic glaze containing 100 G of 20-year old natural uranium – hypothetical parameters

	Dose per individual involved (mrem/yr)					Population dose		
	External		Internal		Total	Probability	Group dose (man-rem/yr)	Total dose (man-rem/yr)
	Direct	Immersion	Inhalation	Ingestion				
Transport								
Truck – long haul								
Drivers – helpers								
([illegible] members)								
Driving	7.85E-02	0.00E-01	0.00E-01	0.00E-01	7.89E-02	1.00E+00	4.02E-02	
Stops – rest	8.80E-05	0.00E-01	0.00E-01	0.00E-01	8.80E-05	1.00E+00	4.49E-05	
Accident – cargo fire	0.00E-01	7.05E-12	7.25E-03	0.00E-01	7.25E-03	3.50E-03	1.29E-05	
Total dose – drivers – helpers								4.02E-02
Persons at stops								
(5.100E+03 members)								
Normal activities	1.10E-05	0.00E-01	0.00E-01	0.00E-01	1.10E-05	1.00E+00	5.61E-05	
Total dose – persons at stops								5.61E-05
Persons along route								
(3.570E+07 members)								
Normal activities	3.83E-08	0.00E-01	0.00E-01	0.00E-01	3.83E-08	1.00E+00	1.37E-03	
Total dose – persons along route								1.37E-03
Motorists								
(3.570E+04 members)								
Passing trucks	1.92E-06	0.00E-01	0.00E-01	0.00E-01	1.92E-06	1.00E+00	6.84E-05	
Total dose – motorists								6.84E-05
Total dose – truck – long haul								4.17E-02
Total dose – transport								4.17E-02
Use								
Commercial use								
Dishwashers								
(5.000E+02 members)								
At work	3.44E+01	1.13E-12	1.26E-03	0.00E-01	3.44E+01	1.00E+00	1.72E+01	
Total dose – dishwashers								1.72E+01
Servers – waiters								
(1.000E+03 members)								
At work	7.93E+00	1.42E-13	1.57E-04	0.00E-01	7.93E+00	1.00E+00	7.93E+00	
Total dose – servers – waiters								7.93E+00
Patrons								
(7.500E+06 members)								
Dining out	1.80E-01	0.00E-01	0.00E-01	3.49-03	1.83E-01	1.00E+00	1.37E+03	
Total dose – patrons								1.37E+03
Passersby								
(9.990E+07 members)								
Normal activities	1.15E-08	0.00E-01	0.00E-01	0.00E-01	1.15E-08	1.00E+00	1.15E-03	
Total dose – passersby								1.15E-03
Total dose – commercial use								1.40E+03
Total dose – use								1.40E+03
Disposal								
Landfill								
Collectors								
(3.000E+01 members)								
At work	3.21E-03	0.00E-01	0.00E-01	0.00E-01	3.21E-03	1.00E+00	9.63E-05	
Total dose – collectors								9.63E-05
Passersby								
(1.000E+05 members)								
Passing cans	2.31E-05	0.00E-01	0.00E-01	0.00E-01	2.31E-05	1.00E+00	2.31E-03	
Total dose – passersby								2.31E-03
Fill workers								
(4.000E+01 members)								
At work	1.15E-06	0.00E-01	0.00E-01	0.00E-01	1.15E-06	1.00E+00	4.59E-08	
Total dose – fill workers								4.59E-08
Area users								
(1.000E+06 members)								
Normal activities	8.25E-07	0.00E-01	0.00E-01	0.00E-01	8.25E-07	1.00E+00	8.25E-04	
Total dose – area users								8.25E-04
Total dose – landfill								3.23E-03
Total dose – disposal								3.23E-03
Emergencies								
Transport accident								
Firemen								
(5.000E+00 members)								
Firefighting	1.40E-03	8.81E-11	9.07E-02	0.00E-01	9.21E-02	1.00E+00	4.60E-04	
Total dose – firemen								4.60E-04
Policemen								
(2.000E+00 members)								
Crowd control	2.58E-04	8.81E-11	9.07E-02	0.00E-01	9.09E-02	1.00E+00	1.82E-04	
Total dose – policemen								1.82E-04
Medical team								
(3.000E+00 members)								
First aid	6.45E-05	2.20E-11	2.27E-02	0.00E-01	2.27E-02	1.00E+00	6.82E-05	
Total dose – medical team								6.82E-05
Total dose – transport accident								7.10E-04
Total dose – emergencies								7.10E-04
Grand total dose								1.40E+03

For skin contact of 1.0 hours the beta dose is 0.5090390E–01 rads.

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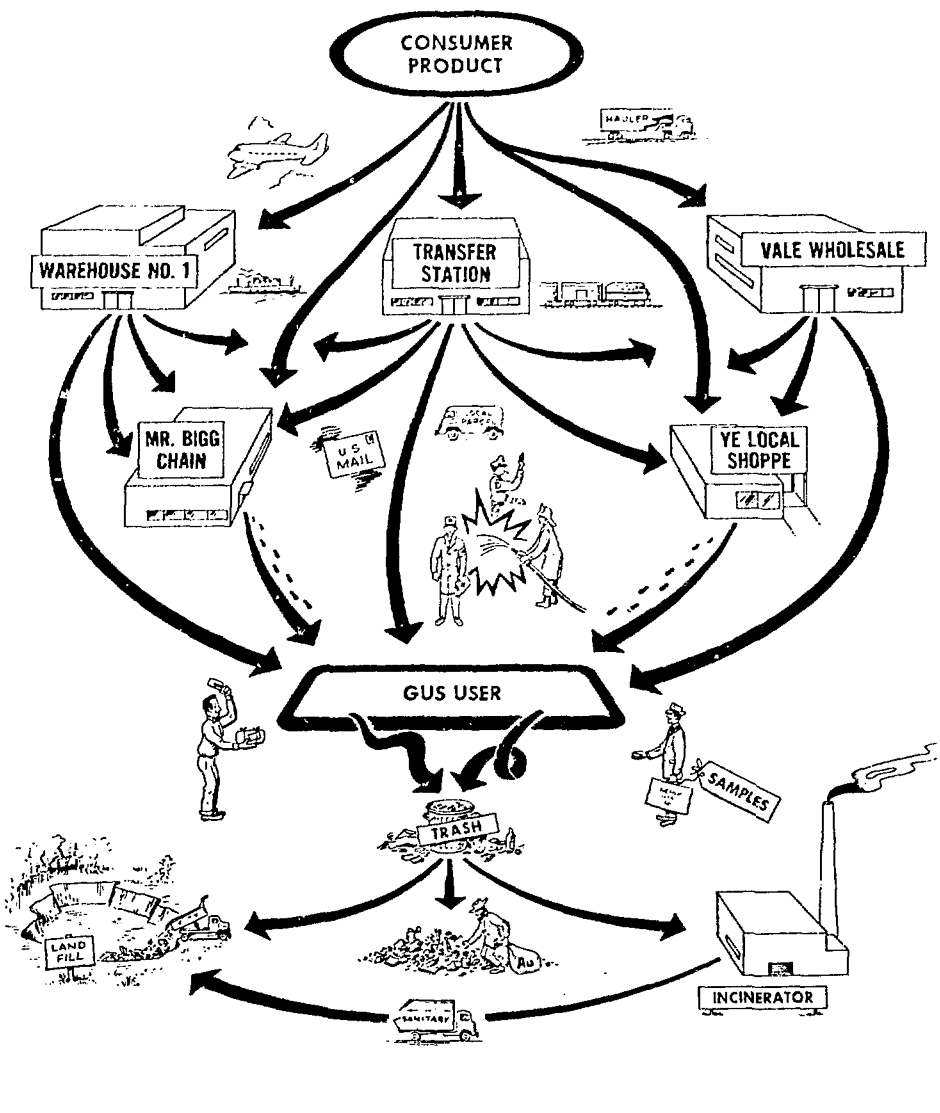

Figure 1. The life of a consumer product.

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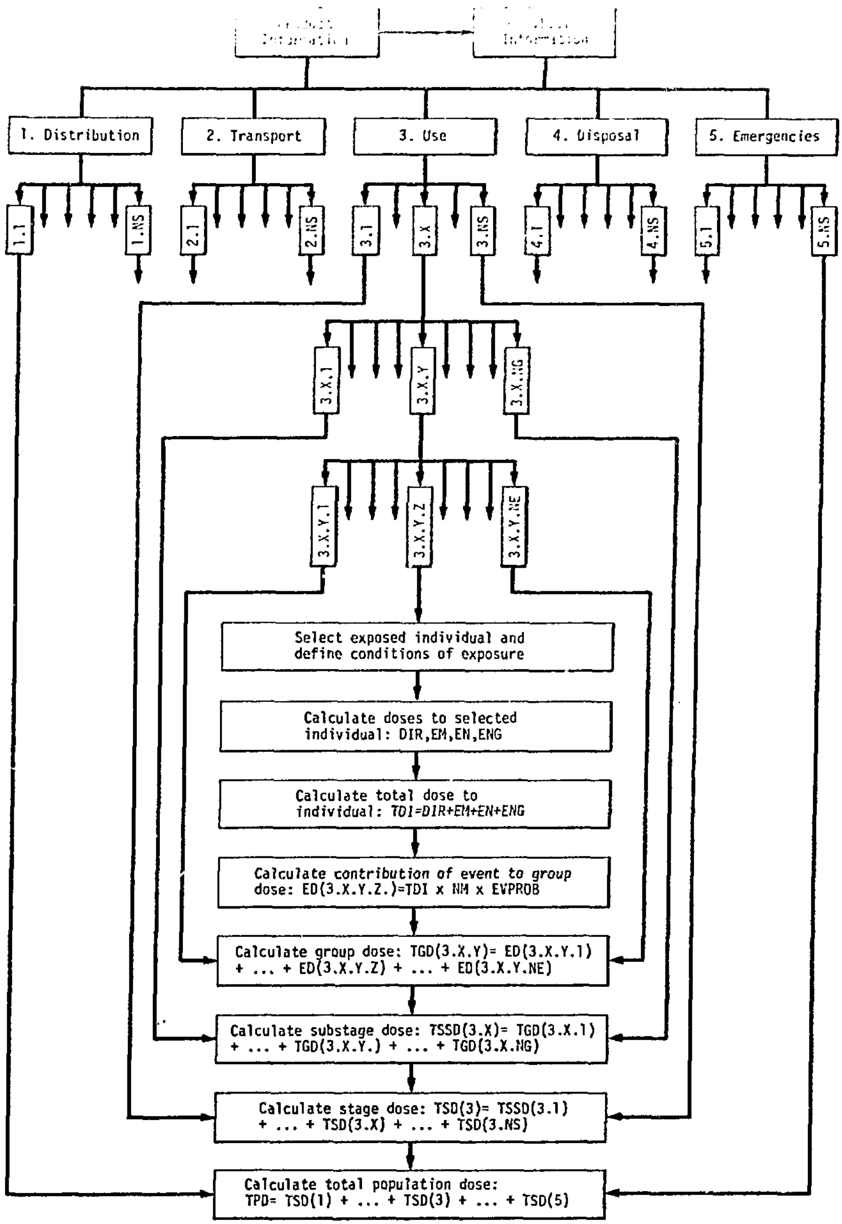

Figure 2. Flow chart of the life-span model and the dose calculations used in CONDOS.